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REPRODUCTION IN THE BROWN RAT (MUS NORWEGICUS)

NEWTON MILLER

Clark University, Worcester, Mass.

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In view of the fact that the brown rat is playing such an important rôle in the economic field and the medical world at the present time, it is of interest if not of practical value to know the details of its reproduction. The life history of this species as lived in its natural environment is as yet imperfectly known. It was to bridge this deficiency in our knowledge that data were obtained on a number of rats kept in the laboratory from November 5, 1909, to December 8, 1910. My results may be much different from those of natural conditions, yet I am convinced that the results obtained are not radically different from what actually takes place in nature where shelter is good and food abundant.

Two sets of cages of four each were built. The first consisted of revolving cages, a foot wide and eighteen inches in diameter with nesting boxes, measuring 8 × 5 × 5 inches, suspended from the axles. These cages were similar to those used by Slonaker. The second set of cages were rectangular, measuring 24 × 24 × 8 inches. These were made of screening, three wires to the inch. For the sake of cleanliness the cages were suspended, as shown in Fig. 1. Newspapers were spread beneath all the cages to catch the excrement and removed as occasion demanded.

In all the cages, siphon watering troughs were used; *i. e.*, bottles held upright with their mouths dipping into shallow dishes. Open vessels were objectionable because rats drop their excrement as they climb about in the cage, thus polluting the water.

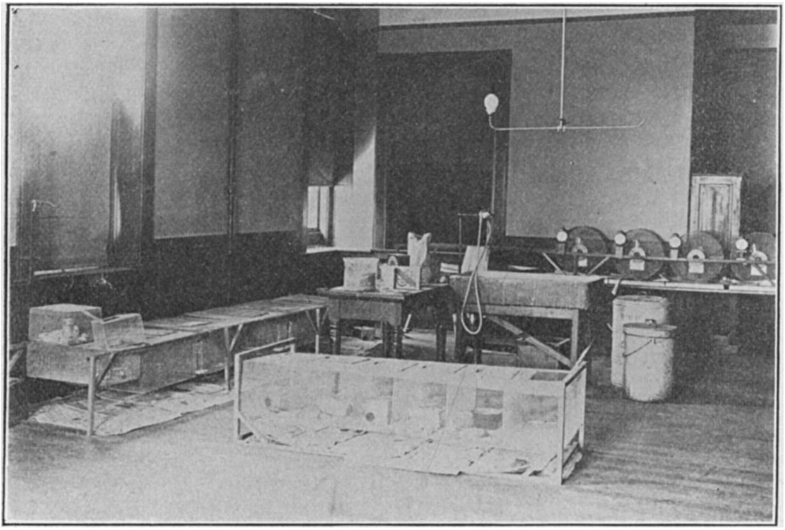

FIG. 1. Showing the plan of the cages.

The experiment was started November 5, 1909, with seven pairs of rats which had just been caught. For convenience, each pair was numbered, the first four being in the revolving cages and the other three in the stationary. The pairs numbered 1, 2 and 5 were old (adults), the females apparently having given birth to young. The others were probably in their third to sixth months and had not given birth.

Female No. 6, after giving birth to young on December 31, 1909, was severely injured by her mate. The wound was not yet healed September 12, 1910, when she was killed, at which time she was found pregnant. The following table is the reproductive record of the other six pairs.

REPRODUCTIVE RECORD. FIRST GENERATION

Date	No. of Pair	No. of Litter	No. of Young	Male	Female	
Feb. 4, 1910	1	1				All eaten February 5. Male not taken away.
Feb. 26, 1910	7	2				All dead-part eaten February 28. Male taken away February 26.
Feb. 27, 1910	1	3	11	5	6	Male taken away February 27.
Mch. 14, 1910	2	4				All dead July 21. Male not taken away.
Mch. 22, 1910	3	5				Male taken away March 22.
Mch. 22, 1910	4	6	7	4	3	
Apr. 7, 1910	7	7	12			All dead April 10.
May 4, 1910	7	8				All eaten May 9.
May 16, 1910	2	9				
May 22, 1910	3	10				
May 22, 1910	1	11	12	4	8	Male not removed.
June 1, 1910	7	12				All eaten June 3. Male removed before birth.
June 4, 1910	5	13				All eaten June 4. Male removed before birth.
June 30, 1910	7	14				All eaten July 6. Male removed before birth.
July 23, 1910	7	15				All dead July 24. Male removed before birth.
Aug. 24, 1910	4	16				All eaten August 27. Male not removed before birth.
Sept. 3, 1910	5	17				
Sept. 5, 1910	7	18	11	4	7	Male removed before birth.
Sept. 8, 1910	2	19	10			All dead September 29. Male removed before birth.
Sept. 20, 1910	1	20				Four still alive. Male removed before birth.
Sept. 20, 1910	3	21	10	6	4	Nine still alive. Male removed before birth.
Sept. 26, 1910	4	22				All eaten. Male removed before birth.
Sept. 26, 1910	5	23				All eaten. Male not removed before birth.
Oct. 17, 1910	2	24				All eaten. Male not removed before birth.
Oct. 20, 1910	5	25				All eaten. Male removed before birth.
Nov. 26, 1910	4	26				All eaten. Male removed before birth.
Nov. 26, 1910	7	27				Part eaten. Male removed before birth.

REPRODUCTIVE RECORD. SECOND GENERATION

Females of Litter No. 11

Date	No. of Female	No. of Litter	No. of Young	Male	Female	
Oct. 15, 1910.	11–2	28				All eaten. Male removed.
Oct. 17, 1910.	11–5	29				All eaten. Male removed.
Oct. 24, 1910.	11–6	30	9			Part eaten — others removed. Male removed.

The works of Lantz and Boelter lead us to infer that the brown rat breeds the whole year round. My rats gave birth to young from February to December, inclusive, and, since they were seen mating in November, December and January, it is safe to say that they produce young in January, also, which gives their breeding period as the whole year.

The gestation period was found to be 23½ to 25½ days, counting from the time of the first copulation. If 23½ days is the shortest time, then females Nos. 1 and 7 must have mated on February 4 and June 30, respectively, the days they gave birth and also ate their young.

Frequently a female eats her young and when she does so, she may breed immediately. It is seen from the table that female No. 7, which had the habit of devouring her young, gave birth to seven litters at intervals of about thirty days; *i. e.*, taking February 2 as the date of conception for her first offspring, she produced, seven litters in seven months.

If the young are reared, a second litter may be produced in two months. Some do not give birth so soon, which may be due, largely to the fact that a female is not sure of conceiving at any given copulation. Daniel's experiment with white mice seems to have some bearing on this point. He found that a female suckling a large litter, carried the second longer, as much as ten days over the average gestation time. According to my data, the brown rat does not conceive before the last ten days of the lactation period, which should not have so marked an effect on the gestation period as is found in the case of the white mouse, which becomes pregnant as soon as a litter is born.

The number of young in the eight litters which I was able to count varied from seven to twelve, with an average of 10.5. Boelter quotes Brehm as recording a litter of twenty-one. Lantz gives two cases where seventeen embryos were found in one female and nineteen in another. He also thinks that for temperate regions the average litter is not under ten. From the data at hand, we can conclude that a pair of adult rats is capable of rearing fifty to sixty young per year. Zuschlag's theoretical table, as quoted by Boelter, gives sixty-four as the possible number of young at the end of the year, the product of a single pair. In this table Zuschlag assumes eight to be the average number of young per litter, and eight litters per year to be the product of a single pair. On this basis the number of offspring at the end of the second and succeeding years is far in excess to the number computed on experimental data.

Rats begin mating, as a usual thing, about five o'clock P.M., and to obtain the period of gestation, males were placed with the females every day at this hour. If a female was in heat, she was removed to a separate cage with one to three males. At first females were left with the males not more than two hours, in which time many copulations had taken place, but in no case did a pregnancy result. Later, they were left with the males twelve to fifteen hours, and even then, failures to become pregnant far outnumbered the pregnancies.

I have not observed a single case of a female mating with a male smaller than herself. It is not common for an old female, even when in heat, to chase a young male about the cage as though he were a female, not letting him come near her. This same female, if placed with a larger male, which could boss her, would mate with him at once without any opposition. Mating in this case seems to be, to some extent, dependent upon the dominating ability of the male.

The number of coitions during a single period of heat is, apparently, great. In one case a female, placed with four males, mated with them in such rapid succession that fifty attempted coitions per half hour would be a conservative estimate. It is impossible to say how many of these attempts were successful, because the rat requires such a short time (four seconds being a long time) to perform the act, thereby making the details of the process difficult of observation.

The following table is a month's record of seven females kept to determine the frequency of the mating periods. Such periods are indicated by an X. It is

FEMALE

Date	October															November																	
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
No. 11-1																									×								
Wild									×										Pr	egn	an t												
No. 11-4								×											×										No	n-p	reg.		×
No. 11-2										×				×						×									×	No	n-pr	g.	
No. 8									×											×					×					×	No	n-pr	eg.
No. 7	×							×									×				Pr	eng	ant										
No. 4								×										×					Pr	egn	ant								

seen that only one pregnancy occurred as a result of each six times of mating. The table indicates, also, either that the mating periods come irregularly, or that the females come in heat about every five days.

I am convinced that odor is the final test for sex recognition. When rats are placed together, the males assume an aggressive attitude and fight all those that oppose them. The females may, usually do, for a little while, resist the males; but they soon yield. They then lie on their backs entirely passive, while the males nose them about the head and smell of their genital organs. This attitude is frequently taken by pregnant females. The males in such cases have shown their superiority and the females recognize it. From now on there is little fighting on the part of the males, and afterwards they will often permit themselves to be severely punished by the females without injuring them. Copulation does not usually follow the above proceedings.

When males meet, there is a battle royal until one is recognized victor. The conquered, then, tries to elude the stronger, and will not submit to be smelt of as a female. Often males smell of each other, probably determining one another's sex, before beginning the fight. I am sure there is no sex recognition when the fight is begun at once, for the females are treated in the same way.

There is very little courtship among the rats. The male is absolutely silent and the female almost so during the period of heat. A pair which had been together for several months, were seen to arouse from their sleep at five-thirty o'clock, P.M., and begin copulating at once without any preliminaries at all. They had not mated previously during the day.

When a female resists the advances of the male, she does so by fighting him away, as shown in Fig. 2, or by kicking him away with her hind foot; or she may lie on her back, as previously described. On the other hand, a female in full heat is the more active of the two. In one instance, she was seen to clasp the male. If he is not aggressive, she throws herself before him in a crouching position, a procedure which she repeats until he takes notice of her. Again, she may strike his head, as though fighting, until he follows her. A female in full heat is much more active and less pugnacious than at other times.

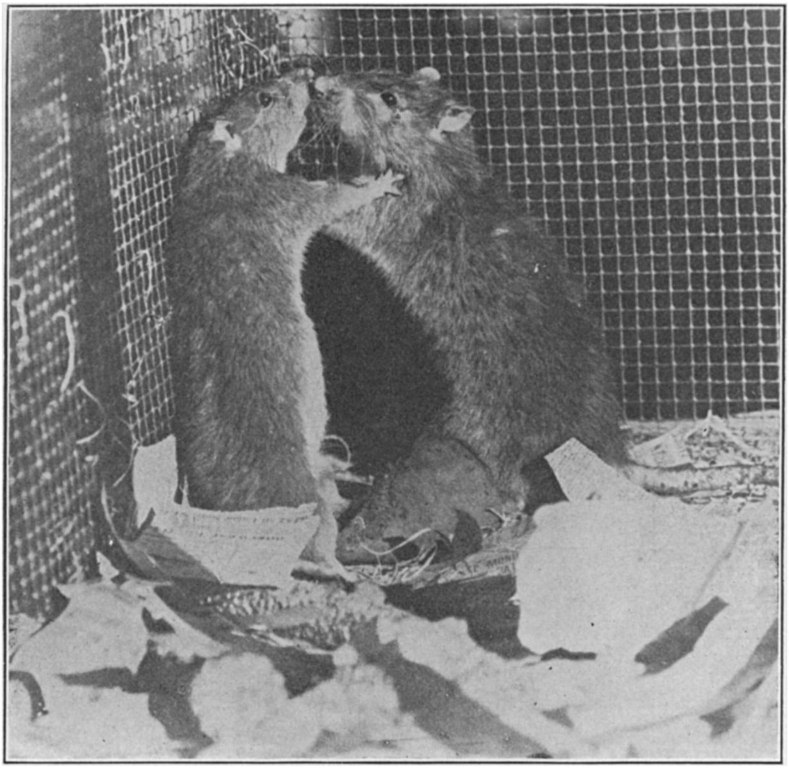

FIG. 2. Rats in a fighting attitude.

We find the anomaly of mammals eating their young carried to an extreme in the case of brown rats kept in confinement. My records show a large per cent. eaten, almost fifty, which has much to do with the number of litters per year, consequently the number of young. This infanticide has usually been attributed to the male, but the young are eaten whether the male is or is not present at the time they are born, which throws the blame on the female. In fact, I have no direct evidence against the male.

The young, when eaten, may be devoured at birth or any time within the next four days. It has been suggested—I think with a little basis for the statement—that disturbing the parents causes them to eat their young. W. T. Hornaday, in a letter, and Bostock state that the large carnivora are kept from all disturbing influences at and about the time they are giving birth. In rare cases some species devour their young if disturbed, but more frequently the young are deserted. My rats were in a room which was kept locked and free from any disturbing influences except my morning visits. Frequently, females by themselves, which built their nests in closed boxes, have had their young and eaten them between my visits. In such cases these females could not have been disturbed. On the other hand, I have taken the young from the nests, weighed them, and even handled them without the mother injuring them when replaced.

Another suggestion is that the rats have not had enough flesh diet and, when the young are born, eat them to satisfy their desire for meat. Here again I think there is no truth, provided plenty of grain and vegetables are accessible. My rats have eaten their young when on a meat-grain-vegetable diet, as well as when on a grain-vegetable allowance.

Dr. Slonaker suggests that the same motive, which leads the rats to eat their dead under natural conditions, might also cause them to eat their helpless young. This is in accord with the rat's habit of killing off its weak.

One of the reasons for eating the young, I think, might be found in the habit that mammals have of thoroughly licking their young, and in many cases eating the embryonic membranes, even among the herbivorous animals. It seems but a little step from the eating of the placenta to the devouring of the young. There may be some truth in all these theories, but I doubt if the principal cause has yet been suggested.

Care of the Young

Before the young are born, the female builds a nest as elaborate as the means at hand will permit. Almost any sheltered nook about buildings is a suitable nesting place for the brown rat. On the farm, in addition to breeding about buildings, it digs its burrows in the field and nests in old straw stacks and grain still in the shock. The nest consists for the most part of a coarse substance such as straw or corn husks, with a lining of a softer material, especially feathers when obtainable. Blue found that where rats use run-ways, they nest in a branch leading off from the main course. This branch is in the form of a Y with the nest in one arm and a storehouse in the other.

The young at birth are entirely helpless. The mother gets them all together and then huddles over them for hours at a time. She never lies on her side to let the young suck; she always crouches over them while the young lie on their sides or backs to get hold of the teats. Usually all the young nurse at the same time, and a litter of twelve, at about weaning time, almost holds the female off her feet while they suck.

The female can easily be induced to move her young elsewhere by disturbing the nest. The young only a few days old are caught around the body by the mother, but if they are a week or so old, she takes hold of them by the skin. In the latter case they are carried much as a kitten is carried by its mother.

In the laboratory the female spends most of her time with the young; some even carry all their food into the nests. Taking food into the nest is a common habit of the rat and must not be considered as a trait peculiar to females with young.

Growth

The young at birth weigh on an average 6.4 grams. The males are a little the larger, measuring in body length 52 mm. as compared with 49 mm. for the females. They also weigh more, and by the end of the second week are as much as two grams heavier.

Very little change is noted in the appearance of the young the first two days, save a gain in size and strength. On the third day a change in color can be detected. The flesh tint is being replaced by a darker hue with a decided tinge of blue on the distal portion of the tail. Curiously enough, the tail is the first to show any marked change of color. On the fourth day, the tail is still darker and the flesh color of the dorsal parts has been replaced by a gray with a touch of blue. Up to this time, no hair is noticed except the vibrissæ. By the end of the week the body is covered with a thin coat of very fine hair, which gives a delicate bluish-brown color. The coloring of the legs begin about this time with the palms of the feet, the joints of the toes and legs turning a bluish tint. The tail, in the meantime, has darkened almost to the base and the nose turned nearly black. On the eighth or ninth day, the gray of the adult is noticed on the back of the head and neck, and with this as a center, it spreads until about the eighteenth day, when the whole color is that of the adult with the exception that it is darker and softer.

The following is a diary of litter No. 18 for the first twenty-five days. The weights given are the averages for the whole litter.

Day	Wt. Grams	Notes
1	6.1	Flesh color; blind; ears closed; helpless.
2	6.4	Able to right themselves if turned over.
3	7.2	Color changing to bluish tint on the dorsal parts; tail coloring from the distal end; no hair except vibrissæ.
4	8.1	Flesh color limited to the ventral parts; creeping about in the nest.
5	9.0	Color a bluish-brown on the back and sides.
6	9.8	
7	10.7	
8	11.5	Sparsely covered with short fine hair.
9	12.3	Faint brownish tinge on the back of the head and neck; tail a dull blue except about 4 mm. at its base; joints of the feet and legs, also the palms of the hind feet, blue; under parts, pinkish.

10	13.0	Dorsal parts, a delicate brown; nose, almost black; incisors appear in the upper jaw.
11	13.8	Heels almost black; rest of coloring the same as yesterday; one seen sitting up and washing its face.
12	14.8	Lower incisors appear (all the incisors appear on the same day in some cases; usually the lower appear a day later than upper).
13	15.1	All the dorsal parts are brown.
14	16.0	
15	16.9	
16	17.9	Eyes beginning to open; one young attempted to bite me.
17	18.8	All have their eyes open; color the same as that of the adults except that it is darker and softer.
18	19.8	
19	20.2	
20	21.0	
21	20.9	Found the young hungry and when given a dog-biscuit, they ate it greedily. It is probable that they began taking solid food the first or second day after cutting their lower incisors, and judging from their weights, yesterday was the first day they did not have food they could eat.
22	23.0	
23	23.9	
24	24.9	
25	25.9	From now on there is little change noticed except increase in size. The young have grown rapidly from the first without the initial loss of weight as found in human infants, or even a marked retardation as found in guinea-pigs by Minot.

During the sixth week the young are weaned. At this time they weigh fifty to seventy grams, and are able to take care of themselves, provided food is abundant. I have seen a number of rats of about this age and size wandering about, in or around farm buildings, apparently, in a starved condition. Presumably, these had just been weaned and were unable to find suitable food.

If food has been abundant the males, by the end of the sixth month, weigh 230 to 290 grams while the females weigh 170 to 240 grams. The male and female of one of my pairs, kept throughout the year and which I judged to be in their third month when caught, weigh 337 grams and 223 grams, respectively. My old male No. 5 weighs 460 grams and my oldest female, 345 grams. These data indicate that a rat does not reach its full growth before the end of the eighteenth month.

Sexual maturity is attained much sooner than full growth. One female of litter No. 11 conceived on the day she was four months old, hence giving birth to her first young in her fifth month. The males are sexually mature as soon as the females, and I have seen some indications that they may be mature early in their fourth month.

Conclusions

1. The brown rat breeds in every month of the year.
2. The gestation period is $23\frac{1}{2}$ to $25\frac{1}{2}$ days.
3. The number of young per litter varies from six to nineteeeen with an average of between ten and eleven.
4. Five or six litters may be reared by a single pair in a year.
5. Seven litters were born in seven months by one female and, presumably, twelve would be produced in the course of a year when all the young perish at birth.
6. There is very little courtship among the brown rats.
7. Odor is the primary factor in sex recognition; the aggressiveness of the male is second.
8. Brown rats in captivity eat almost fifty per cent. of their young at birth. Most of the young eaten, if not all, are eaten by the females.
9. Full growth is attained not under eighteen months.
10. Sexual maturity is reached at least by the end of the fourth month in both sexes.

REFERENCES

Blue, R., '08. The Underlying Principles of Anti-plague Measures. California State Journal of Medicine, August. Reprinted in "Eradicating Plague from San Francisco," 1909, p. 217.

Boelter, W. R., '09. The Rat Problem, pp. 6 (note), 88.

Bostock, F. R., '04. The Training of Wild Animals, pp. 40, 50.

Daniel, J. F., '10. Observations on the Period of Gestation in White Mice. *Journal of Experimental Zoology*, Vol. 9, No. 4, p. 868.

Lantz, D. E., '10. Natural History of the Rat. Public Health and Marine Hospital Service of U. S., pp. 22, 23.

Minot, C. S., '08. The Problem of Age, Growth and Death, p. 94.

Slonaker, J. R., '08. A Description of an Apparatus for Recording the Activity of Small Mammals. *Anatomical Record*, June, Vol. 2, pp. 116–122.